

# NSTAR Ion Propulsion System Power Electronics

High-specific-impulse ion propulsion systems (IPS's) have long been targeted as candidates for the primary propulsion systems of both planetary and Earth-space spacecraft, and as auxiliary propulsion systems for geosynchronous communications spacecraft. Major issues with ion propulsion systems are the system cost and complexity, especially in the power processing unit (PPU). In some cases, the PPU's have contained over 4000 discrete parts and 12 power supplies to operate the thruster.

The NASA Solar Electric Propulsion Technology Application Readiness (NSTAR) program, managed by the Jet Propulsion Laboratory (JPL), is currently developing a high-performance, simplified ion propulsion system. This propulsion system, which is throttleable from 0.5- to 2.3-kW output power to the thruster, targets primary propulsion applications for planetary and Earth-space missions and has been baselined as the primary propulsion system for the first New Millennium spacecraft.

The NASA Lewis Research Center is responsible for the design and delivery of a breadboard PPU and an engineering model thruster (EMT) for this system and will manage the contract for the delivery of the flight hardware to JPL. The PPU requirements, which dictate a mass of less than 12 kg with an efficiency of 0.9 or greater at a 2.3-kW output, forced a departure from the state-of-the-art ion thruster PPU design. Several innovations--including dual-use topologies, simplified thruster control, and the use of ferrite magnetic materials--were necessary to meet these requirements.

To reduce the level of complexity and parts count in the PPU, designers at Lewis employed a dual-use concept for the discharge and neutralizer power supplies. The dual-use topology derives power for the cathode heater and anode from the same power transformer, allowing the construction of a single inverter each for the neutralizer and discharge power supplies. This topology selection reduced the number of power supplies necessary to operate the thruster to four. Further simplifications were realized in the PPU with the application of a single closed loop, implemented in a microcontroller, for thruster control. This loop regulates the beam current, and thus the thrust produced, by varying the discharge current. Completed breadboard power supplies are shown in the photograph.



*Three breadboard power-supply modules.*

To minimize mass and optimize the efficiency of the breadboard, we set the switching frequency of the power supplies which operate the thruster at 50 kHz. This frequency selection represents a compromise between low mass and high efficiency, and it also allows the power transformers to be designed and fabricated with ferrite (ceramic) cores. If packaging of ferrite components for spaceflight becomes an issue, this frequency is still within the usable range of metallic core transformers that have an extensive heritage in flight designs.

A breadboard version of the PPU was fabricated to validate the dual-use concept and verify closed-loop stability within the individual power supplies and with the thruster. The breadboard, which was integrated with a 30-cm ion thruster, demonstrated autonomous control and stable steady-state operation of the thruster over the full throttling range. The total component mass of the breadboard as built is 6.2 kg, and the efficiency is on the order of 0.9. A simplified user interface facilitates thruster operation via a data terminal, with thruster operations reduced to a single on/off command.